The Effect of Sodium Content in Food on the appetite of the Obese People: A Research Proposal on Cognitive Diversity

Xinfeng Wu, Rui Wu

Abstract

Previous studies showed that people with obesity respond to high- or low-calorie foods differently from those with the standard Body Mass Index (BMI). Nevertheless, as suggested by the previous paper, sodium might be a clue that leads to high-calorie food intake, which then induces obesity. Also, the synergy between eating high-calorie food and high-sodium food was found to be one of the mechanisms that developed obesity. However, no study has been done to investigate the effect of sodium food on the appetite of people suffering from obesity. To find out this question, we will conduct behavior tests, including lexical decisions and visual stimulation, to determine whether the sodium component in the food can be a way to define the food stimuli that develop eating addiction in obesity population. Besides, we will compare which delivery of this kind of stimuli, through pictures or words, will affect the results more, if possible.

Keywords: Sodium level, Obesity, Lexical decision, Visual stimulation, Attentional bias

Introduction

Obesity, defined as having a BMI of 30 kg/m^2 or greater, has nearly tripled globally since 1975 [1]. More than 1.9 billion individuals were overweight; of these, 650 million were obese in 2016 [1]. Obesity is clinically meaningful since it is linked to a significant increase in all-cause mortality. What is more, obesity is also a substantial risk factor for type II diabetes, cardiovascular-related disease, fatty liver, sleep apnea, and osteoarthritis; several types of cancer may also be produced as complications [1-3].

Current therapies for obesity include lifestyle modifications, pharmaco- and psychotherapy, bariatric surgery, and other personalized combination treatment [4-6]. However, the above treatment of obesity is hampered by poor effectiveness and a substantial risk of weight regaining [7]. This kind of unsatisfied treatment outcome is due in part to a lack of encouragement from the healthcare providers as well as the unsustained modification to the diet quality of the patients, which indicates the vital role of appetitive pathways in treating obesity. However, the understanding of the factors that affect appetites remains unclear.

Obesity has been connected to genetic and epigenetic variables in its aetiology [8]. Furthermore, energy intake that exceeds energy expenditure is the primary driver of weight gain. In this sense, obesity is caused by a long-term or surfeit positive energy balance [9-10]. Aside from these well-known characteristics, there is mounting evidence that obesity has certain parallels with addictive behaviours. Traditionally, addiction was defined as excessive intake of chemicals that resulted in physical dependency, marked by tolerance and withdrawal. Besides substance addiction, compulsive involvement in behaviours like gambling, sex, or eating was regarded as non-substance addiction, and the impulse to participate in these habits was merely psychological [11]. Recently, the conceptual paradigm of drug addictions has started to shift, with a greater focus on substance use behaviors rather than the molecular features of the substances themselves. It's becoming evident that repeatedly engaging in numerous actions may cause physiological changes in the brain comparable to those seen in drug addicts. Consequently, addiction, according to contemporary theories, is a condition that manifests itself via a range of distinct behaviours. In this regard, overeating might be one of these habits. The yearning to overeat has been found to be stimulated by the scene or the odour of the food. According to a previous paper, if a person is regularly exposed to food cues, the sight or smell of food may serve as a conditional stimulus for the people to consume [12]. Therefore, food hunger and the brain's sensitivity to food signals are conditional responses to conditional stimuli. And the food cues can be a point to studying the relationship between obesity and food intake.

Unsurprisingly, a large number of studies regarding food cues and response from people has been conducted among participants in various age ranges, different genders, or in divergent testing methods. However, the food cues in these studies were categorized only by high or low calories. The 13th General Program of Work (GPW13) suggested that the Health Assembly approved in 2018 that salt/ sodium might be a potentially harmful substance that leads to several obesity-related symptoms like hypertension [13]. Also, previous studies found that sodium intake was correlated to the increase in BMI and the risk of cardiovascular diseases both in the human and mice models [14-16]. Some people thought that these results might be because high-calorie foods tend to be high in sodium, especially fast foods like chips and fries. Indeed, foods like cottage cheese are also high in sodium but are deemed to be healthy and not in high calories per serve. In 2015, researchers from British and Chinese found out that an additional gram of salt each day elevated the risk of obesity in children by 28% and in adults by 26%, which indicates that exceeding salt intake could be an independent risk factor for obesity [17]. Correspondingly, we think sodium content in the food might be an independent stimulus for appetite. Similar to the calorie in the food, salt content in the food might be a potential cue to stimulate the appetite of people, so that increase food intake.

Article IV. Proposed studies: Is the reaction to food stimuli in various sodium content differ among the people suffering from obesity?

The proposed study addresses (i.) if the salt/sodium content in the food can affect the food appetite among people suffering from obesity and (ii.). which kind of delivery of this stimulus will affect the people's appetite the most. This study will measure the mean reaction time from groups of ordinary and obese people after the recognition tests. The test stimuli will be presented as words and pictures, respectively. To resolve these questions, we will follow the lexical tests carried out by Tárrega *et al.* [18] and the visual stimulation by food pictures conducted by Duszka *et al.* [19].

Method

Participants. 60 participants aged between 65 and 74 will be randomly recruited because studies have found the obesity rate to be the highest in this age range [20]. Moreover, the participants will be divided into two groups according to their BMI: non-obesity people (BMI<30.0) and obese people (BMI≥30.0). SDS scoring tests should be done ahead of the experiment to eliminate the confounding of the appetite of participants brought by the mental disorder.

Recognition tests: lexical decisions and visual stimulation. In our experiment, our stimulus used will focus on the sodium concentration within the food. After delivering the stimulus, we will analyze the participants' latency data of reaction to foods at different sodium levels. In the lexical test, we will prepare 45 words with high and low sodium foods from Food Dictionaries and Encyclopedias provided by the U.S. National Agricultural Library (USDA). And in the visual stimulation, we will find the pictures that correspond to these food words by searching in the food-pics database built up by Blechert et al. [21].

The experimental sessions should be taken place at noon. All participants should have a breakfast consisting of a liquid and a solid piece of food in the morning. Both recognition tests will be brought out on the computer. In each trial, a fixation point (+) will be presented for 500 ms in the center of the computer screen. Then, the target word (always in lowercase, in black on a white background) or the picture of the foods (white background) will be presented in the center of the computer screen until the participant responds or until 3000 ms elapse. The inter-trial interval is 1.5 s. Participants will be told that they should answer the question if they are pleased to see this picture/words or not—Z ("yes") or M("no"). In each test, the task will include a practice block of 16 stimuli (4 words/pics in high sodium food, four words/pics in low sodium food, and eight pics/words that are not food) followed by three blocks of 60 stimuli each (15 words/pics in high sodium food, 15 words/pics in low sodium food, and 30 pics/words that are not food). The order of the items in the experimental blocks will be randomized for each participant. The latency of the reaction to Z ("yes") will be calculated at last to measure participants' preference for foods in high sodium and low sodium.

Predictions. According to the review by Liu *et al.* [22], obesity might be a kind of bodily trait that supports the body-specific hypothesis because obese people might respond to different food stimuli. Based on this approach, we will be taking on speculation to conclude that obese people might react differently toward food with high or low sodium levels. Ma *et al.* state that taking in sodium causes adult body weights to grow significantly [23]. Also, people usually have a shorter reaction time when hearing or watching their preferred things [24]. We, therefore, predict that people with obesity will have a shorter reaction time towards the high sodium food cues and vice versa in the non-obesity group. RT distribution analysis with a delta plot will also be used to analyze the preference for sodium levels in the food throughout the sample groups. It is predicted that people with healthy weight will have a similar preference towards both low sodium food and high sodium food which will show a flat line in the delta plot and the intercept will around zero. In contrast, people with obesity will have a significant distributional difference in RT between low-sodium and high-sodium stimuli that the intercept in the delta plot will be far away from zero. We will also focus on the percentile and momentum change in this group, here we expect that the trend of increments may similar to the results from Tárrega's study that obesity will have an obvious rising with longer mean RT, but the results in the healthy group will tend to be stable [18].

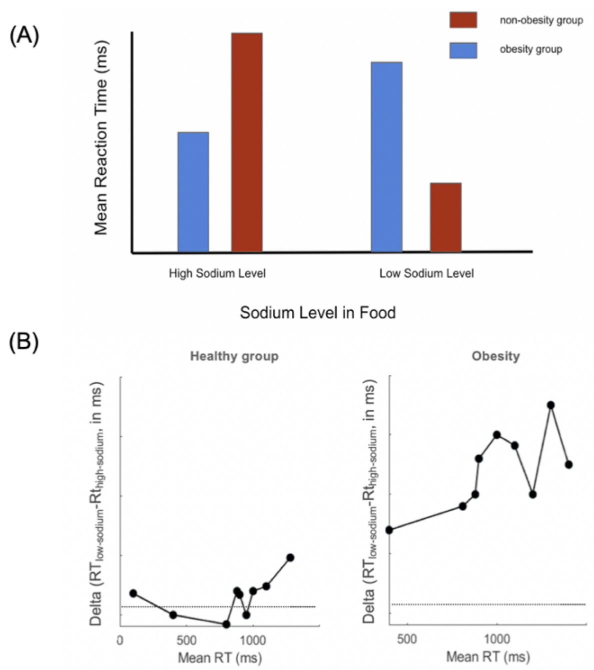

Figure 1. Predictions of the proposed study. (A) People with obesity will have a shorter reaction time towards the high sodium food cues and longer for the low sodium food cues. Correspondingly, a conversed resulted will be showed in the healthy weight group. (B) Distribution of the mean RTs.

Conclusion

As obesity is a category of illness that can lead to several mortal complications, it is still urgent to find novel preventions and treatments. Diet adjustment is one of the well-known methods for preventing and treating obesity. In our proposal, we convey two subtle methods to investigate the attentional biases to food-relative stimuli in people with obesity. In our potential analysis, rather than just comparing the RT, we will focus on the distribution of RTs by using incremental plots. This kind of quantile-based method can provide converging evidence to our predictions. If the result of the study supports the predictions (Fig 1.), we can give one more aspect of suggestions for a healthy diet with significant theoretical and clinical implications. However, this outcome will still lead to questions about whether other factors can synergize with sodium levels in food on people's appetite. Past studies on high sodium intake correlation with obesity have suggested that the pathophysiologic mechanism of obesity has high relation with ghrelin [25]. As noted, ghrelin acts as a regulator of fats and appetite, thus relating to the pathogenesis of obesity. In future studies, it is recommended to imply a sodium-related food stimulus to measure the amount of ghrelin in a dish which can also consider the role of ghrelin in affecting a participant's weight. Although we exclude the mental disorder confounding in our proposed studies, past studies have shown that mood disorders affect an adult's appetite [26]. Hence, we can investigate a further step on how people with mental disorders prefer salty food, which is related to obesity. In this case, the correlation between salt/sodium intake and obesity can be tested more accurately. As for the recording methods, EEG and fMRI may also be used to determine how food stimuli affect cognitive function from the aspect of neurons or cells level.

Reference

1. WHO. (2022). *Obesity and overweight*. Who.int. Retrieved 24 June 2022, from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

2. Flegal, K. M., Kit, B. K., Orpana, H., & Graubard, B. I. (2013). Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA, 309*(1), 71–82. https://doi.org/10.1001/jama.2012.113905

3. Heymsfield, S. B., & Wadden, T. A. (2017). Mechanisms, Pathophysiology, and Management of Obesity. *The New England journal of medicine, 376*(15), 1492. https://doi.org/10.1056/NEJMc1701944

4. Dalle Grave, R., Sartirana, M., & Calugi, S. (2020). *Personalized cognitive-behavioural therapy for obesity (CBT-OB): theory, strategies and procedures. BioPsychoSocial medicine, 14*, 5. https://doi.org/10.1186/s13030-020-00177-9

5. Jacob, J. J., & Isaac, R. (2012). Behavioral therapy for management of obesity. *Indian journal of endocrinology and metabolism, 16*(1), 28–32. https://doi.org/10.4103/2230-8210.91180

6. Jensen, M. D., Ryan, D. H., Apovian, C. M., Ard, J. D., Comuzzie, A. G., Donato, K. A., Hu, F. B., Hubbard, V. S., Jakicic, J. M., Kushner, R. F., Loria, C. M., Millen, B. E., Nonas, C. A., Pi-Sunyer, F. X., Stevens, J., Stevens, V. J., Wadden, T. A., Wolfe, B. M., Yanovski, S. Z., Jordan, H. S., … Obesity Society (2014). 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation, 129*(25 Suppl 2), S102–S138. https://doi.org/10.1161/01.cir.0000437739.71477.ee

7. Hall, K. D., & Kahan, S. (2018). Maintenance of Lost Weight and Long-Term Management of Obesity. *The Medical clinics of North America, 102*(1), 183–197. https://doi.org/10.1016/j.mcna.2017.08.012

8. Thaker V. V. (2017). GENETIC AND EPIGENETIC CAUSES OF OBESITY. *Adolescent medicine: state of the art reviews, 28*(2), 379–405.
9. Hill, J. O., Wyatt, H. R., & Peters, J. C. (2012). Energy balance and obesity. *Circulation, 126*(1), 126–132. https://doi.org/10.1161/CIRCULATIONAHA.111.087213
10. Romieu, I., Dossus, L., Barquera, S., Blottière, H. M., Franks, P. W., Gunter, M., Hwalla, N., Hursting, S. D., Leitzmann, M., Margetts, B., Nishida, C., Potischman, N., Seidell, J., Stepien, M., Wang, Y., Westerterp, K., Winichagoon, P., Wiseman, M., Willett, W. C., & IARC working group on Energy Balance and Obesity (2017). Energy balance and obesity: what are the main drivers?. *Cancer causes & control : CCC, 28*(3), 247–258. https://doi.org/10.1007/s10552-017-0869-z
11. Zou, Z., Wang, H., d'Oleire Uquillas, F., Wang, X., Ding, J., & Chen, H. (2017). Definition of Substance and Non-substance Addiction. *Advances in experimental medicine and biology, 1010*, 21–41. https://doi.org/10.1007/978-981-10-5562-1_2
12. Boswell, R. G., Sun, W., Suzuki, S., & Kober, H. (2018). Training in cognitive strategies reduces eating and improves food choice. *Proceedings of the National Academy of Sciences of the United States of America, 115(48)*, E11238–E11247. https://doi.org/10.1073/pnas.1717092115
13. WHO. (2018). Who.int. Retrieved 25 June 2022, from https://www.who.int/docs/default-source/documents/replace-transfats/replace-action-package.pdf.
14. Yi, S. S., & Kansagra, S. M. (2014). Associations of sodium intake with obesity, body mass index, waist circumference, and weight. *American journal of preventive medicine, 46*(6), e53–e55. https://doi.org/10.1016/j.amepre.2014.02.005
15. Wójcik, M., & Kozioł-Kozakowska, A. (2021). Obesity, Sodium Homeostasis, and Arterial Hypertension in Children and Adolescents. *Nutrients, 13*(11), 4032. https://doi.org/10.3390/nu13114032
16. Lanaspa, M., Kuwabara, M., Andres-Hernando, A., Li, N., Cicerchi, C., & Jensen, T. et al. (2018). High salt intake causes leptin resistance and obesity in mice by stimulating endogenous fructose production and metabolism. *Proceedings Of The National Academy Of Sciences, 115*(12), 3138-3143. https://doi.org/10.1073/pnas.1713837115
17. Ma, Y., He, F. J., & MacGregor, G. A. (2015). High salt intake: independent risk factor for obesity?. *Hypertension (Dallas, Tex. : 1979), 66*(4), 843–849. https://doi.org/10.1161/HYPERTENSIONAHA.115.05948
18. Tárrega, J., Perea, M., Rojo-Bofill, L. M., Moreno-Giménez, A., Almansa-Tomás, B., Vento, M., & García-Blanco, A. (2021). Do children with overweight respond faster to food-related words?. *Appetite, 161*, 105134. https://doi.org/10.1016/j.appet.2021.105134
19. Duszka, K., Gregor, A., Reichel, M. W., Baierl, A., Fahrngruber, C., & König, J. (2020). Visual stimulation with food pictures in the regulation of hunger hormones and nutrient deposition, a potential contributor to the obesity crisis. *PloS one, 15*(4), e0232099. https://doi.org/10.1371/journal.pone.0232099
20. ABS. (2018). *National Health Survey: first results, 2017–18*, ABS website, Retrieved 26 August 2022, from National Health Survey: First results, 2017-18 financial year | Australian Bureau of Statistics (abs.gov.au).
21. Blechert, J., Meule, A., Busch, N., & Ohla, K. (2014). Food-pics: an image database for experimental research on eating and appetite. *Frontiers In Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00617
22. Liu, C., Li, Y., & Wu, Z. (2021). Body-specificity Effects on Different Bodily Traits. *Advances In Social Science, Education And Humanities Research*. https://doi.org/10.2991/assehr.k.211011.083
23. Ma, Y., He, F. J., & MacGregor, G. A. (2015). High salt intake: independent risk factor for obesity?. *Hypertension (Dallas, Tex. : 1979), 66*(4), 843–849. https://doi.org/10.1161/HYPERTENSIONAHA.115.05948
24. Duszka, K., Gregor, A., Reichel, M. W., Baierl, A., Fahrngruber, C., & König, J. (2020). Visual stimulation with food pictures in the regulation of hunger hormones and nutrient deposition, a potential contributor to the obesity crisis. *PloS one, 15*(4), e0232099. https://doi.org/10.1371/journal.pone.0232099
25. Zhang, Y., Li, F., Liu, F., Chu, C., Wang, Y., & Wang, D. et al. (2016). Elevation of Fasting Ghrelin in Healthy Human Subjects Consuming a High-Salt Diet: A Novel Mechanism of Obesity?. *Nutrients, 8*(6), 323. https://doi.org/10.3390/nu8060323
26. Restivo, M. R., McKinnon, M. C., Frey, B. N., Hall, G. B., & Taylor, V. H. (2016). Effect of obesity on cognition in adults with and without a mood disorder: study design and methods. *BMJ open, 6*(2), e009347. https://doi.org/10.1136/bmjopen-2015-009347